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(71) Applicant: CRANE PLASTICS COMPANY LLC
[US/US]; 2141 Fairwood Avenue, P.O. Box 1047, Colum-
bus, OH 43216 (US).

(72) Inventors: HUTCHISON, Herbert, L.; 1148 Poppy Hills
Drive, Blacklick, OH 43004 (US). BRANDT, Jeffrey, R.;
2080 Havens Court East, Blacklick, OH 43004 (US).

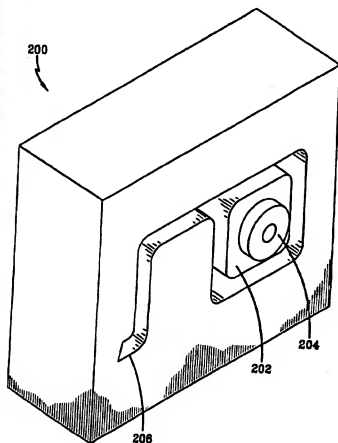
(74) Agents: STANDLEY, Jeffrey, S. et al.; Standley &
Gilester LLP, 495 Metro Place South, Suite 210, Dublin,
OH 43017 (US).

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(54) Title: COLLING OF EXTRUDED AND COMPRESSION MOLDED MATERIALS



(57) Abstract: The present invention relates to a system and a method for cooling extruded and molded materials. The present invention is especially useful to thoroughly cool an extrudate by directing a cooling fluid toward a surface of the extrudate (e.g., an interior surface that defines a hollow portion of an extrudate). Hollows may be created in order to reduce material, weight, and/or processing time. A cooling fluid is diverted toward the surface of the extrudate so as to cool the material and assist in solidification. A baffle may serve to divert the cooling fluid in the desired direction. Increases in production line throughput may result by rapidly cooling the molded material. In addition, the more efficient cooling may be achieved with a lesser amount of the cooling fluid, and the velocity and temperature of the cooling fluid may be reduced. Other uses for the present invention include injection molding, compression molding, gas assist molding, and co-extrusion.

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COOLING OF EXTRUDED AND COMPRESSION MOLDED MATERIALS

This is a continuation-in-part of U.S. Application No. 10/025,432, filed
5 December 19, 2001, which is a continuation-in-part of U.S. Application No.
09/766,054, filed January 19, 2001, each of which is hereby incorporated by
reference in its entirety.

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates generally to a system and method for cooling
10 manufactured articles and, more particularly, to a system and method for cooling
extruded and molded materials with a fluid that is below about 80 degrees
Fahrenheit. The present invention may also be used in other types of manufacturing
techniques in which the output or material must be cooled from a heated state. The
present invention includes a system and method for cooling synthetic wood
15 composite materials including, but not limited to, cellulosic-filled plastic composites.
In addition, the present invention may also be used to cool other types of pure or
mixed materials including, but not limited to, plastics, polymers, foamed plastics,
plastic compositions, inorganic-filled plastic compositions, metals, metallic
compositions, alloys, mixtures including any of the aforementioned materials, and
20 other similar, conventional, or suitable materials that need to be cooled after being
processed. For instance, the present invention may be used to cool polyvinyl
chloride (PVC) products and products made from other plastics.

For several reasons, there is a need to find materials that exhibit the look and
feel of natural wood. The supply of wood in the world's forests for construction and
25 other purposes is dwindling. Consequently, the supply of wood from mature trees

has become a concern in recent years, and the cost of wood has risen. As a result, several attempts have been made by others to find a suitable wood-like material.

Cellulosic/polymer composites have been developed as replacements for all-natural wood, particle board, wafer board, and other similar materials. For example, U.S. Patent Nos. 3,908,902, 4,091,153, 4,686,251, 4,708,623, 5,002,713, 5,055,247, 5,087,400, 5,151,238, 6,011,091, and 6,103,791 relate to processes and/or compositions for making wood replacement products. As compared to natural woods, cellulosic/polymer composites offer superior resistance to wear and tear. In addition, cellulosic/polymer composites have enhanced resistance to moisture, and it is well known that the retention of moisture is a primary cause of the warping, splintering, and discoloration of natural woods. Moreover, cellulosic/polymer composites may be sawed, sanded, shaped, turned, fastened, and finished in the same manner as natural woods. Therefore, cellulosic/polymer composites are commonly used for applications such as interior and exterior decorative house moldings, picture frames, furniture, porch decks, deck railings, window moldings, window components, door components, roofing structures, building siding, and other suitable indoor and outdoor items. However, many attempts to make products from cellulosic/polymer composite materials have failed due to poor or improper manufacturing techniques.

In the present invention, a product or article is manufactured by a desired technique such as, but not limited to, extrusion, compression molding, injection molding, or other similar, suitable, or conventional manufacturing techniques. The product is then cooled by subjecting it to a cooling fluid. The present invention can be used alone or in conjunction with other known or later developed cooling

methods. Accordingly, the present invention can more thoroughly and efficiently cool the manufactured product or article to a desired level. This can lead to faster production times as well as a product having improved structural, physical, and aesthetic characteristics.

5 In addition to the novel features and advantages mentioned above, other objects and advantages of the present invention will be readily apparent from the following descriptions of the drawings and exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross sectional view of an extrudate.

10 Figure 2 is a view of an extrusion die showing an exemplary location of a cryogenic nozzle.

Figure 3 is an elevation view of one embodiment of a system implementing the present invention.

Figure 4 is a partial cross sectional view along the line A-A of Figure 3.

15 Figure 5 is a partial elevation view of another embodiment of a system of the present invention.

Figure 6 shows a sectioned schematic of an extruder line used in accordance with the practice of one embodiment of the present invention.

20 Figure 7 is a cross sectional view from a lateral side angle of an exemplary die of the present invention.

Figure 8 is a cross sectional view from a top side angle of the die of Figure 7.

Figure 9 is a cross sectional view from an exit side angle of the die of Figure 7.

Figure 10 is a cross sectional view from a lateral side angle of an exemplary die of the present invention that includes a baffle.

Figure 11 is a cross sectional view from a lateral side angle of another exemplary die of the present invention that includes a baffle.

5 DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENT(S)

The present invention is directed to a system and method for cooling manufactured articles or products. It is not intended to limit the present invention to particular manufacturing techniques or particular materials. The present invention may be used to cool articles or products made by variety of different manufacturing techniques. Examples of manufacturing techniques that may utilize the present invention include, but are not limited to, extrusion (including co-extrusion), compression molding, injection molding, and other known, similar, or conventional techniques for manufacturing products or articles from plastic, wood, metal, mixtures of these materials, or other materials used to make products.

15 The present invention is particularly useful for cooling plastics, polymers, and cellulosic/polymer composite materials that have been extruded or molded. The materials that may be used to make cellulosic/polymer composites include, but are not limited to, cellulosic fillers, polymers, plastics, thermoplastics, inorganic fillers, cross-linking agents, lubricants, process aids, stabilizers, accelerators, inhibitors, enhancers, compatibilizers, blowing agents, foaming agents, thermosetting materials, and other similar, suitable, or conventional materials. Examples of cellulosic fillers include sawdust, newspapers, alfalfa, wheat pulp, wood chips, wood fibers, wood particles, ground wood, wood flour, wood flakes, wood veneers, wood laminates, paper, cardboard, straw, cotton, rice hulls, coconut shells, peanut shells,

20

bagass, plant fibers, bamboo fiber, palm fiber, kenaf, flax, and other similar materials. In addition to PVC, examples of polymers include multilayer films, high density polyethylene (HDPE), polypropylene (PP), low density polyethylene (LDPE), chlorinated polyvinyl chloride (CPVC), acrylonitrile butadiene styrene (ABS), ethyl-

5 vinyl acetate, other similar copolymers, other similar, suitable, or conventional thermoplastic materials, and formulations that incorporate any of the aforementioned polymers. Examples of inorganic fillers include talc, calcium carbonate, kaolin clay, magnesium oxide, titanium dioxide, silica, mica, barium sulfate, acrylics, and other similar, suitable, or conventional materials. Examples of thermosetting materials

10 Include polyurethanes, such as isocyanates, phenolic resins, unsaturated polyesters, epoxy resins, and other similar, suitable, or conventional materials. Combinations of the aforementioned materials are also examples of thermosetting materials. Examples of lubricants include zinc stearate, calcium stearate, esters, amide wax, paraffin wax, ethylene bis-stearamide, and other similar, suitable, or conventional

15 materials. Examples of stabilizers include tin stabilizers, lead and metal soaps such as barium, cadmium, and zinc, and other similar, suitable, or conventional materials. In addition, examples of process aids include acrylic modifiers and other similar, suitable, or conventional materials.

Figure 1 shows one example of an extrudate 100 that may be cooled by the

20 present invention. The extrudate 100 includes an exterior surface 102, a hollow 104, an interior surface 106, and two ends 108. The exterior surface 102 may be cooled by a traditional method such as using a warm water bath or water mist. However, the interior surface 106 may not be sufficiently cooled by many traditional methods because the surface may not be available for contact with the cooling

medium. The interior surface 106 defines the boundary of the hollow 104. The interior surface 106 may be accessed from either end 108. The interior surface 106 may not be cooled to a desired level within a desired amount of time by externally applied coolants.

5 Figure 2 shows one example of an extrusion die 200 adapted with the present invention. The extrusion die 200 defines the cross section of the extrudate by the shape of the profile form/flow channel 206. Hollows in the cross section of the extrudate are each formed with a standing core 202. The standing core 202 is fitted with a nozzle 204. The nozzle 204 is adapted to connect with a source of the
10 cooling fluid (not shown). The nozzle 204 is oriented to spray into the hollow formed in the extrudate cross section by the standing core 202.

 Figure 3 shows one example of a system 300 that may utilize the present invention. The system 300 includes an extruder 302 and an extruder 304. In this example, a crosshead die 306 puts a cap layer from the extruder 304 on the material
15 extruded by the extruder 302. A container 308 may be used to hold a cooling fluid of the present invention. The fluid is used to cool the extruded product or article 312 after it exits the die 306. In this embodiment, a valve is used to control the release of gas, e.g., vapor, from the fluid. A hose, conduit, tube, or any other suitable transfer device 310 may be used to direct the gas from the container 308 to the
20 desired location for cooling the extruded product 312. The transfer device 310 may be formed by one integral component or a plurality of interconnected components. For instance, a portion of the transfer device 310 may be a passage through the die 306. In this example, the transfer device 310 extends through the die 306 so that the gas is released in the hollow of the extruded product 312 after it exits the die

306. In this manner, the present invention can provide efficient and thorough cooling of the extruded product 312. Moreover, the extruded product 312 may be further introduced into a liquid bath 314, a spray mist chamber 316, and/or any other desired cooling system to achieve additional cooling of the extruded product 312 if
5 desired. Examples of the liquid bath 314 and the spray mist chamber 316 are provided in U.S. Patent No. 5,827,462.

Depending on the type of cooling fluid and the desired expulsion rate of the cooling fluid, the container 308 may be pressurized. The container 308 may be connected to a compressor, e.g., an air compressor or any other similar, suitable, or
10 conventional compressing device, in order to maintain the desired pressure in the container 308. Additionally, the container 308 may be in fluid communication with a blower or a pump to obtain the desired expulsion rate of the cooling fluid from the container 308. A blower in fluid communication with the container 308 may also be utilized to accelerate the cooling fluid to a desired velocity after it has been expelled.

15 Figure 4 is a cross section view along the line A-A of Figure 3. The extruded product 312 includes a cap layer 404. The transfer device 310 may extend through the die 306 to a nozzle 406 that releases gas from the cooling fluid into a hollow of the extruded product 312. In this instance, gas vapor 402 permeates through the hollow of the extruded product 312, thereby providing much improved cooling of the
20 extruded product 312. In fact, the inventors have surprisingly discovered that using the present invention to inject the cooling fluid into a hollow portion of a product may be sufficient to thoroughly cool the entire product, i.e., the inside and the outside of the product. As a result, the present invention may eliminate the need to provide another cooling system to cool the outer surface of the product.

It should be recognized that Figures 3 and 4 are merely one example of a manufacturing system that may utilize the present invention. As noted above, the present invention may be used in any manufacturing system in which the processed material needs to be cooled to a desired level. For example, the present invention
5 may be used in an extrusion system consisting of a single extruder that is in-line with a die. Also, the present invention may be used to cool any type of material including, but not limited to, injection molded materials and compression molded materials.

It should also be recognized that the cooling fluid of the present invention
10 may be expelled elsewhere relative to the manufactured product (i.e., other than in a hollow portion of the product). For example, Figure 5 shows an embodiment in which the gas vapor 500 is dispersed by the transfer device 502 onto the exterior of the product 504. The present invention also includes dispersing multiple streams of the cooling fluid onto the same or different portions of the manufactured product.
15 For instance, flows of the cooling fluid may be simultaneously dispersed onto the exterior and interior surfaces of the manufactured product.

Turning to Figure 6, this Figure shows a sectioned schematic of an extruder line 600 used in accordance with the practice of one embodiment of the present invention. Figure 6 shows an extruder line 600 which includes co-extrusion
20 apparatus 602. Co-extrusion apparatus 602 includes insulated transport tube 604 that is adapted to carry cooling fluid 606. The cooling fluid 606 may be gas that may be delivered from a supply of cryogenic fluid. Co-extrusion apparatus 602 also includes a cross head extruder 608 which is adapted to prepare the thermoplastic material 610 for extrusion through a die which forms a hollow, rectangular profile and

urges it along longitudinal direction 612. Further layers of thermoplastic material such as layer 614 may be added through the use of additional extruders such as extruder 616. Such additional layers of thermoplastic material may include layers of material with specific characteristics for exterior use, such as fluoropolymers and PVC having greater or lesser durability and resistance to changes in aesthetic appearance resulting from exposure to weather and environmental/atmospheric conditions, as dictated by the desired end user. The thermoplastic material 610 is formed by the forming die 618 into the desired final shape, such as a rectangular cross-section. The cooling fluid 606 permeates through the hollow space created in thermoplastic material 610. The cooling fluid 606 may be at a significantly lower temperature than the surrounding thermoplastic material 610. The cooling fluid 606 cools the thermoplastic material 610, assisting the thermoplastic material to "skin" or solidify.

Figures 7 through 9 show a cross sectional view of one example of a die 700 that is configured to be in-line with an extruder. The extruded material flows through the die in the direction indicated by arrow 702. In this example, the resultant extrudate 704 defines three hollow portions that are separated by webs 706 and 708. The cooling fluid enters the die 700 through passages 710. In some embodiments, it should be recognized that a tube, conduit, or any other type of transfer device may extend through the passages 710 for directing the flow of the cooling fluid through the passages 710. The cooling fluid exits the die 700 through passages 710 in the direction indicated by arrows 712. In such an embodiment, the passages 710 intersect the path of flow of the extruded material through the die 700. In other words, the passages 710 intersect the flow channel in the die 700.

The die 700 may be heated to a sufficient level to facilitate extrusion and limit premature curing of the extrudate in the die 700. In this example of an in-line system, the passages 710 actually extend through the die 700, intersecting the path of flow of the extruded material through the die 700. In such embodiments, it may be preferable to limit cooling of the die 700 by the cooling fluid in the passages 710. Accordingly, the passages 710 may be insulated by a suitable material. For example, the passages 710 may be lined with ceramic insulation, putty ceramics, or any other similar, suitable, or conventional insulating material in order to limit undesired heat loss by the die 700. In fact, it should be recognized that the transfer device for the cooling fluid in any type of embodiment may be insulated in order to limit undesired cooling of surrounding items.

As best seen in the example of Figure 9, the passages 710 may be substantially surrounded by die material 714 even where the passages 710 intersect the path of flow of the extruded material. In this manner, direct contact between the extruded material and the passages 710 may be avoided, if desired. The die material 714 surrounding the passages 710 may be heated to facilitate the extrusion process. Also, air gaps may be provided between the die material 714 and the passages 710 for additional insulation.

Any desired cooling fluid may be used in the present invention. In one exemplary embodiment, the cooling fluid, e.g., gas or liquid, may have a temperature below about 80 degrees Fahrenheit, more preferably below about 68 degrees Fahrenheit, still more preferably below about 32 degrees Fahrenheit, even more preferably below about minus 100 degrees Fahrenheit. On the other hand, the temperature may be above about minus 325 degrees Fahrenheit, more preferably

above about minus 300 degrees Fahrenheit, still more preferably above about minus 275 degrees Fahrenheit, even more preferably above about minus 250 degrees Fahrenheit. However, in some embodiments of the present invention, the cooling fluid may be above about 80 degrees Fahrenheit or below about minus 325 degrees Fahrenheit. Examples of the cooling fluid are air and water. Another example of the cooling fluid is gas or vapor that is produced from a cryogenic fluid. For instance, a cryogenic fluid may have a temperature below about minus 250 degrees Fahrenheit. Examples of cryogenic fluids include, but are not limited to, liquid oxygen, liquid nitrogen, liquid neon, liquid hydrogen, liquid helium, and other similar, suitable, or conventional cryogenic fluids.

In addition to the temperature, the velocity of the cooling fluid may also impact its effectiveness. By selecting a suitable velocity and temperature of the cooling fluid, the inventors have discovered that an entire product can be thoroughly cooled just by injecting the cooling fluid into a hollow portion of the product. The velocity of the cooling fluid may be greater than about 10 miles per hour, more preferably greater than about 40 miles per hour, and it may be less than about 100 miles per hour, more preferably less than about 50 miles per hour. However, it should be recognized that the velocity of the cooling fluid may be less than about 10 miles per hour or greater than about 100 miles per hour in some embodiments.

The efficiency of the present invention may be further increased by diverting the flow of the cooling fluid toward the surface of the extruded product as it exits the die. By concentrating the cooling fluid on a surface of the extrudate, the desired amount of cooling may occur more quickly resulting in the use of less cooling fluid as compared to non-diversion methods. Moreover, the increased cooling efficiency

enables the use of warmer cooling fluids and a reduction in the velocity of the cooling fluid as compared to non-diversion methods. For example, this embodiment of the present invention may be particularly useful if it is desired to use a cooling fluid that is warmer than about 80 degrees Fahrenheit. However, it should be
5 recognized that, in many embodiments, it may be desirable to use a cooling fluid below about 80 degrees Fahrenheit for optimal cooling efficiency.

Figure 10 shows one example of a die that is adapted to divert a cooling fluid toward a surface of an extruded project. The die 800 of this embodiment may include any of the optional or preferred features of the die 700 shown in Figures 7
10 through 9. The cooling fluid may enter the die 800 through a passage 810. A baffle 820 is in fluid communication with the passage 810 such it receives the cooling fluid. The baffle 820 is adapted to then divert the flow of the cooling fluid such that it is directed to a desired surface of the extrudate. By directing the cooling fluid toward a surface of the extrudate, the baffle 820 may also create a more turbulent flow of the
15 cooling fluid (as compared to a straight line flow that is not directed toward a surface of the extrudate) which further enhances the efficiency of the cooling process. The baffle 820 may be any device or structure that is suitable for diverting the flow of the cooling fluid to the desired location (e.g., an interior or exterior surface of a product). In this particular example, the baffle 820 is adapted to divert the cooling fluid in the
20 direction of arrows 830 toward an interior surface of a hollow portion of the extrudate. For this purpose, the baffle 820 includes an inner conical portion 840 that forces the cooling fluid in the direction of arrows 830.

Figure 10 shows one example of a design of a baffle 820. It should be recognized that the design of a baffle of the present invention may vary so as to

divert the cooling fluid in the desired direction. Of course, the desired direction will vary according to the type of product being extruded and the location of the baffle relative to the extruded product.

The baffle 820 may be placed in fluid communication with the passage 810 in any suitable manner. In the example of Figure 10, the baffle 820 is secured to an end portion of a conduit 850 that extends through the passage 810. The baffle 820 may be secured to the end portion of the conduit 850 in any desired manner. For example, the baffle 820 may be threaded, i.e., screwed, onto the end portion of the conduit 850. For other examples, the baffle 820 may be secured to the conduit 850 using other mechanical means (e.g., screws, pins, and other types of mechanical fastening devices) and/or adhesives. As previously noted, the conduit 850 may be insulated. The baffle 820 may also be insulated, if desired. The baffle 820 is offset from the heated portion 860 of the die 800 in this particular example. Optionally, there may be an insulated layer 870 on an exit end of the die 800. The insulated layer 870 may be useful to prevent the cooling fluid from cooling the heated portion 860 of the die 800.

Figure 11 shows another example of a die which may include any of the optional or preferred features of the other embodiments of the present invention. In this embodiment, the die 900 includes a passage 910 that is in fluid communication with the baffle 920. The baffle 920 is not offset from the heated portion 930 of the die 900 in this example. In order to limit undesired cooling of the heated portion 930, it may be preferred to use an insulated baffle 920 or otherwise provide a layer of insulation between the baffle 920 and the heated portion 930. As in the previous example, the baffle 920 may be connected to a conduit 940 that lines that passage

910. It should also be recognized that the baffle 920 may be placed in fluid communication with the passage 910 in any other suitable manner. For example, the baffle 920 may have a threaded connection with the heated portion 930. In other examples, the baffle 920 may be connected to the heated portion 930 using other
5 mechanical means (e.g., screws, pins, and other types of mechanical fastening devices) and/or adhesives. As in the previous example, an exit end of the die 900 may include a layer of insulation 950.

The exemplary embodiments herein disclosed are not intended to be exhaustive or to unnecessarily limit the scope of the invention. The exemplary
10 embodiments were chosen and described in order to explain the principles of the present invention so that others skilled in the art may practice the invention. Having shown and described exemplary embodiments of the present invention, those skilled in the art will realize that many variations and modifications may be made to affect the described invention. Many of those variations and modifications will provide the
15 same result and fall within the spirit of the claimed invention. It is the intention, therefore, to limit the invention only as indicated by the scope of the claims.

WHAT IS CLAIMED IS:

1. A method for cooling a product, said method comprising:

providing a die, said die having a passage;

extruding a material through said die to form said product, said product

5 having a surface;

directing a cooling fluid through said passage; and

diverting said cooling fluid such that said cooling fluid is directed toward said surface of said product.

2. The method of claim 1 wherein said passage is lined with an insulating

10 material.

3. The method of claim 2 wherein said insulating material is selected from the group consisting of ceramic insulation and putty ceramics.

4. The method of claim 1 wherein said material is selected from the group consisting of plastics, metals, cellulosic/polymer compositions, inorganic-filled plastic

15 compositions, and foamed plastics.

5. The method of claim 1 wherein said cooling fluid has a temperature between about 80 degrees Fahrenheit and about minus 325 degrees Fahrenheit.

6. The method of claim 5 wherein said cooling fluid has a temperature between about 68 degrees Fahrenheit and about minus 300 degrees Fahrenheit.

20 7. The method of claim 6 wherein said cooling fluid has a temperature between about 32 degrees Fahrenheit and about minus 275 degrees Fahrenheit.

8. The method of claim 7 wherein said cooling fluid has a temperature between about minus 100 degrees Fahrenheit and about minus 250 degrees Fahrenheit.

9. The method of claim 1 wherein said cooling fluid is selected from liquid oxygen, liquid nitrogen, liquid neon, liquid hydrogen, liquid helium, and air.
10. The method of claim 1 wherein said cooling fluid is selected from the group selected from liquids, gases, and vapors.
- 5 11. The method of claim 1 wherein said die is in-line with an extruder.
12. The method of claim 11 wherein said passage intersects a path of flow of said material through said die.
13. The method of claim 1 wherein said surface is an interior surface that defines a hollow portion of said product.
- 10 14. The method of claim 1 wherein said surface is an exterior surface of said product.
15. A die adapted to be used with an extruder to form a product, said die comprising:
- a flow channel adapted to be in fluid communication with said extruder such
- 15 that an extruded material is forced through said flow channel to form said product;
- a passage extending through said die, said passage adapted to be in fluid communication with a source of a cooling fluid; and
- a baffle in fluid communication with said passage, said baffle adapted to divert said cooling fluid toward a surface of said product as said product exits said
- 20 die.
16. The die of claim 15 wherein said passage is lined with an insulating material.
17. The die of claim 16 wherein said insulating material is selected from the group consisting of ceramic insulation and putty ceramics.

18. The die of claim 15 wherein said die is adapted to be in-line with said extruder.

19. The die of claim 15 wherein said baffle is situated relative to said flow channel such that said baffle is adapted to divert said cooling fluid toward said surface which
5 is an interior surface that defines a hollow portion of said product.

20. The die of claim 15 wherein said baffle is situated relative to said flow channel such that said baffle is adapted to divert said cooling fluid toward said surface which is an exterior surface of said product.

21. The die of claim 15 wherein said baffle has an inner conical portion adapted
10 to divert said cooling fluid toward said surface of said product.

22. The die of claim 15 further comprising a layer of insulating material on an exit end of said die.

23. A die adapted to be used with an extruder to form a product having an interior surface that defines a hollow portion, said die comprising:

15 a flow channel adapted to be in fluid communication with said extruder such that an extruded material is forced through said flow channel to form said product;

a passage extending through said die and intersecting said flow channel, said passage adapted to be in fluid communication with a source of a cooling fluid; and

a baffle in fluid communication with said passage, said baffle adapted to
20 divert said cooling fluid toward said interior surface of said product as said product exits said die.

24. The die of claim 23 wherein said passage is lined with an insulating material.

25. The die of claim 24 wherein said insulating material is selected from the group consisting of ceramic insulation and putty ceramics.

26. The die of claim 23 wherein said die is adapted to be in-line with said extruder.

27. The die of claim 23 wherein said baffle has an inner conical portion adapted to divert said cooling fluid toward said interior surface of said product.

5 28. The die of claim 23 further comprising a layer of insulating material on an exit end of said die.

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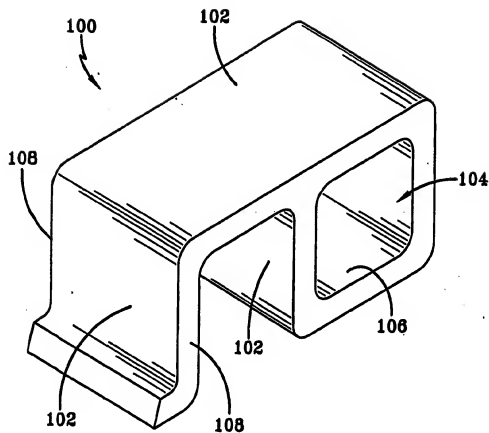


FIG-1

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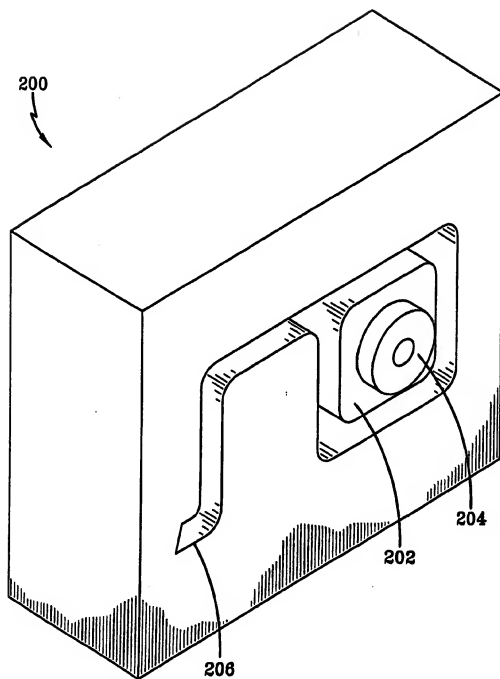
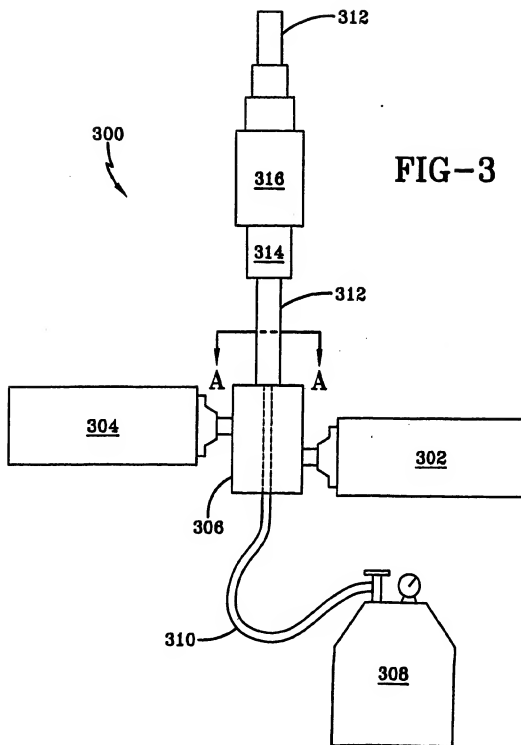


FIG-2

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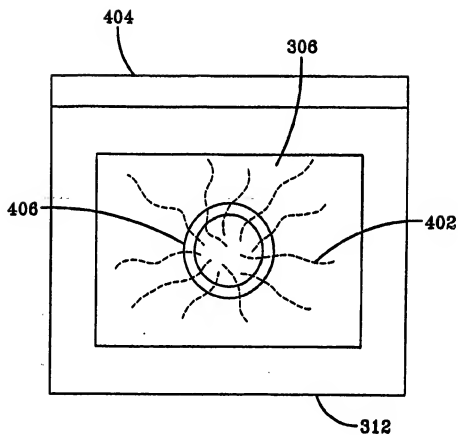


FIG-4

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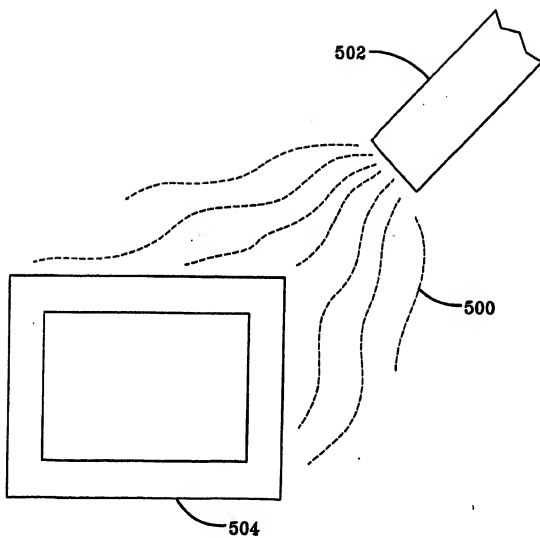


FIG-5

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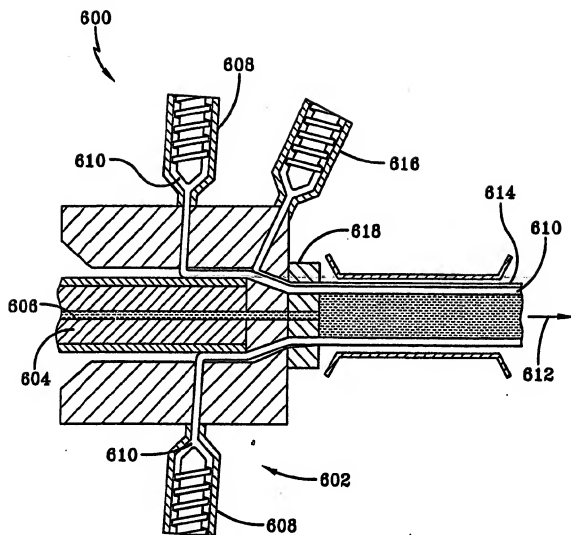


FIG-6

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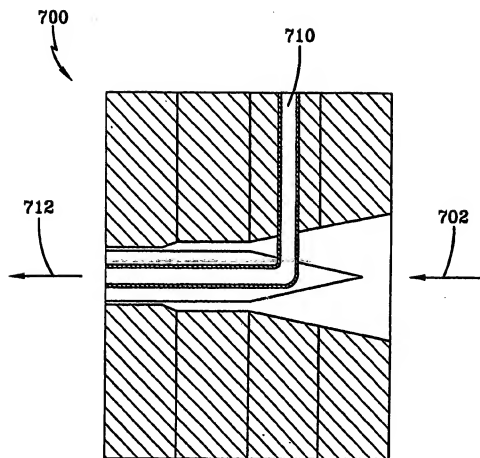


FIG-7

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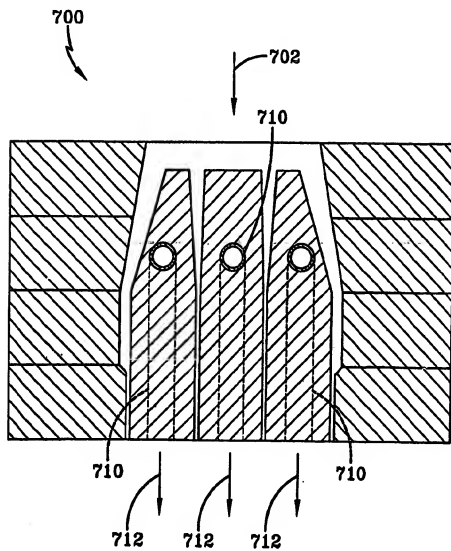


FIG-8

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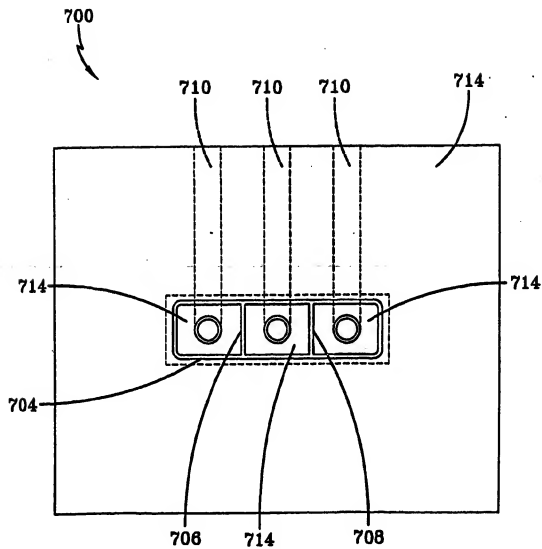


FIG-9

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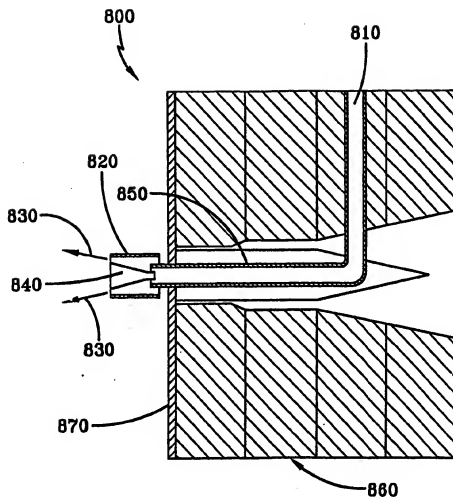


FIG-10

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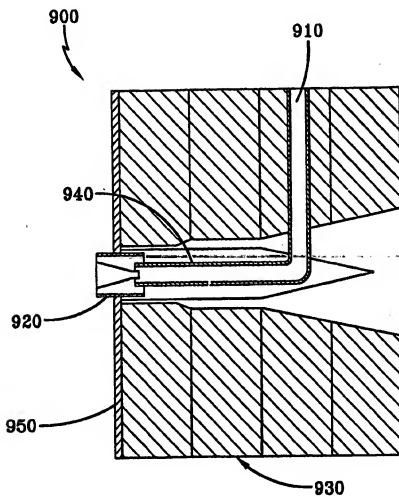


FIG-11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/12990

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : F25D 15/06

US CL : 62/63

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 62/63, 63, 64, 304

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| A | US 3,907,961 A (CARROW) 23 September 1975 (23.09.1975), entire document. | 1-18 |
| A | US 4,130,616 A (CLIFFORD) 19 December 1978 (19.12.1978), entire document. | 1-18 |
| X | US 4,573,893 A (WATERS et al) 4 March 1986 (04.03.1986), entire document. | 1, 10, 13, 14 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents

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document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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document member of the same patent family

Date of the actual completion of the international search

11 JUNE 2003

Date of mailing of the international search report

07 AUG 2003

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Box PCT
Washington, D.C. 20531

Facsimile No. (703) 305-3250

Authorized officer

DENISE ESQUIVEL

Diene Russell for

Telephone No. (703) 305-0249